Editorial

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Insect biotechnology – a major challenge in the 21st century

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The idea to publish this special issue on "Insect Biotechnology" in the *Zeitschrift für Naturforschung C* (ZNC) arose last year at the XXV International Congress of Entomology (ICE) in Orlando (FL, USA), where in several symposia leading academic scientists, researchers and students shared their research results on all aspects of insect biotechnology and molecular biology.

Insect biotechnology or yellow biotechnology can be defined as the use of whole insects, their organs, cells or molecules, but also their symbiotic microbes, in the fields of medicine (red biotechnology), agriculture (green biotechnology) and industry (white biotechnology). The term yellow biotechnology was chosen because of the yellow color of insect hemolymph, which has thus far delivered a number of chemicals, proteins and microbes used in medical, pharmaceutical, agricultural or industrial applications [1].

Insects are the most species rich animal group on earth. To date, approximately 1.1 million species have been described, but their estimated number may be up to 10 million. Insects are mainly terrestrial, but numerous groups have migrated into fresh water. Only one genus of "marine" insects lives on the surface of the sea. Most people consider insects primarily as pests, but there are many more beneficial species than pests. Many insects provide humans with useful materials such as honey, silk or wax. The pollination of crops by insects is of essential importance to man. Harmful insects include those feeding on crops, fruits or seeds, but they can also destroy human resources such as clothes or wood. Blood sucking insects can transmit numerous diseases, e.g. malaria [2].

In the course of their evolution, insects have developed a huge arsenal of active compounds, which they use to defend themselves against enemies and diseases or to explore novel food sources [3]. The main task of insect biotechnology is to make these natural substances available to mankind. Insect biotechnology, therefore, has considerable economic potential and is a key factor for the propagation of biodiversity for the bioeconomy [1, 4, 5].

The systematic development of new products and services based on insects has been pursued for more than 30 years. The greatest advances in insect biotechnology were driven by the developments in modern molecular biology, particularly by the development of techniques, which allowed one to fully sequence the genomes of numerous insect species. Other recently developed molecular techniques can also be used, even if only partial sequence information is available. A milestone in the development of such novel molecular tools was the discovery of RNA interference, which allows a knocking out of individual genes and enabled entomologists to study functions of individual genes in living insects.

A first milestone in the manifestation of insect biotechnology in Europe was the establishment of a European PhD network in Insect Science and Biotechnology under supervision of Professor Francesco Pennacchio (Naples, Italy) in 2002. In Germany, and Europe as a whole, the field of insect biotechnology was greatly enhanced by the foundation of the LOEWE Center for Insect Biotechnology and Bioresources, which is located at the Justus Liebig University and Mittelhessen University of Applied Sciences in Giessen, which closely cooperates with the Fraunhofer Institute for Molecular Biology and Applied Ecology, and various national and international research-based pharmaceutical companies. An independent Fraunhofer Institute for Bioresources in Giessen is in progress.

The present ZNC special issue contains seven contributions from authors that had been invited to submit either a review article or an original research paper on any topic of insect biotechnology. Three of the contributions (Grau et al., Talmann et al. and Weidner et al.) were submitted by members of the LOEWE Center at Giessen. All papers were submitted through the regular review process of the journal. I would like to thank the reviewers for their expertise and Ms. Ulrike Kitzing (de Gruyter, Berlin) for her patience and consideration during the processing of the papers.

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Insect farming is a novel and alternative strategy for the production of protein-rich food for animals and humans. The paper by Grau et al. (Giessen) reviews the mass rearing of the mealworm, *Tenebrio molitor*, for the production of food and feed. The paper particularly focuses on challenges such as the contamination of food products with bacteria from the insect gut and the risk of rapidly spreading pathogens and parasites. They propose trans-generational immune priming and probiotic bacteria as alternative strategies to the use of antibiotics to prevent outbreaks of infections among farm-produced insects. Müller et al. (Dresden) present the black soldier fly, *Hermetia illucens*, as another promising source for sustainable production of proteins, lipids and bioactive substances like antimicrobial peptides.

Four papers focus on the industrial applications of insect derived compounds. Herold and Scheibel (Bayreuth) review recent developments in recombinant insect silk production as well as technical procedures to process recombinant silk protein into fibers, films and hydrogels for biomedical and technical applications. The good mechanical properties of insect silk together with their non-toxic, biocompatible and biodegradable nature renders these materials, e.g. for creating fish nets or to cover wounds.

Insects have acquired the ability to use almost any organic substrate as a food source. Correspondingly large is the variety of enzymes, which are used in the bioconversion of organic compounds, and therefore may be of interest to the bioeconomy. Burse and Boland (Jena) address in their article the biosynthetic route to cyclic monoterpenes (iridroids) in Chrysomelina leaf beetles, which are used as defensive compounds against their enemies. The authors discuss their findings in the context of the already known counterpart pathway in plants and the use of the enzymes in technological applications, e.g. in drug development.

Talmann et al. (Giessen) present some strategies for the construction of insect P450 fusion enzymes. Insect P450 monooxygenases (P450s) are known to catalyze reactions such as the detoxification of insecticides and the synthesis of hydrocarbons, which makes them useful for many industrial processes. However, the utilization of P450s is difficult because they must be paired with a cytochrome P450 reductase (CPR) and both enzymes are membrane anchored. Both problems could be solved by creating fusion proteins that combine P450s and CPR functions without the membrane anchors. The authors discuss several strategies for the construction of such fusion enzymes.

Tupec et al. (Prague) present another group of enzymes with potential for biotechnical applications, namely fatty acid metabolism-related enzymes. They focus on the fatty acyl desaturases and fatty acyl reductases involved in the biosynthesis of fatty acid-derived pheromones. Application of such pheromone-biosynthetic enzymes represents an environmentally friendly and economic alternative to the chemical synthesis of pheromones that are currently being used in insect pest management strategies.

Insect-based expression platforms such as the baculovirus expression vector system (BEVS) are widely used in laboratory- and industrial-scale production of recombinant proteins. In the last paper, Weidner et al. (Giessen) studied the significance of shear forces in different reactor systems, which affect the yield of recombinant proteins produced by insect cells using the BEVS.

The LOEWE Center for Insect Biotechnology will host the 1st Giessen Symposium of Insect Biotechnology from the 9th to 10th October 2017 at the Justus Liebig University. Abstracts of all symposium talks are published in the online edition of this special issue.

Beginning in the winter semester 2017, a new Masters program in "Insect Biotechnology and Bioresources" will be offered at the Justus Liebig University Giessen, which will provide students from all over the world with a challenging and interdisciplinary study in insect biotechnology.

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